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MAINTENANCE FUNCTIONS AND ORGANIZATION STRUCTURE OF MODERN MANAGED MAINTENANCE SYSTEMS **

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1. Introduction and Background

1.1. The Role and Organization of the Czechoslovak Iron and Steel Industry

Czechoslovakia is one of the most industrialized of the Council of Mutual Economic Assistance countries. Industrial manufacturing activity constitutes the largest and most important sector, contributing 65% to the national income. Industry as a whole exceeded the growth target of 5.3%, increasing the industrial production by 5.7%. A major component of the industry are the iron and steel and engineering industries.

The integrated iron and steel industry in Czechoslovakia is today well developed. Amongst the Council of Mutual Economic Assistance (CMEA) steel producers, ČSSR stands third, the first two being USSR and Poland. However, per capita steel production in ČSSR is today higher than USSR and Poland, the figures respectively being 972 kg/per capita compared to about 550 kg/per capita (USSR) and 430 kg/per capita (Poland).

Czechoslovakia has the following 7 large integrated iron and steel works :

1) THE EAST SLOVAKIAN STEELWORKS, Košice (VSŽ) :
   - hot and cold rolled strip producer; 4 million tons/year of main production

2) THE NOVÁ HUŤ KLEMENTA GOTTWALDA, Kunčice (NHKG) :
   - mainly production of hot rolled strip in coil, heavy sections (joints, rounds, channels and angles), wire, tubes; 3.4 mil. tons/year (supplied FRÝDEK MÍSTEK WORKS with hot rolled strip for electrical sheet production)

3) THE TŘINEC IRON AND STEEL WORKS, Třinec (TŘVŘSR) :
   - heavy, medium and light sections, rod, rails, wire; raw steel output 2.6 mil. tons/year

4) THE VÍTKOVICE STEEL WORKS, Ostrava (VŽKG) :
   - rail, billet, heavy, medium and light sections, tube; raw steel output 2.3 mil. tons/year

5) THE KLADNO STEEL WORKS, Kladno (SONP) :
   - stainless, high speed and alloy steel products; 1 mil. tons/year

6) THE CHOMUTOV TUBE ROLLING AND IRON WORKS, Chomutov (VTŽ) :
   - seamless tube producer; 0.4 mil. tons/year

7) THE KRÁLODVORSKÉ ŽELEZÁRNY, Králův Dvůr (KŽ) :
   - flat rolled products, electrical sheets, metallic coated strip, cast iron pressure pipes and fittings; 0.4 mil. tons/year

1.2. Introduction of the Czechoslovak UNDP/UNIDO Project on Computerized Maintenance Systems

The growth of range and costs of maintenance and repairs in Czechoslovak metallurgical industries was represented by a steady 5.5% increase per year during the last decade 1971-80, the value of the new sophisticated installed facilities and rehabilitated production facilities and plant equipment having been more than doubled during that period. Consequently, the demand for both qualified maintenance manpower and management and planning personnel has grown, too, and the necessity for rationalization and improvement in maintenance productivity and planning and management has arisen. In order to meet these needs of metallurgical industries within the framework of Czechoslovak industry development plans, an industrial EDP project "Application of a Modern Maintenance System in the Iron and Steel Industry" (Code Number DP/CZE/77/005) was agreed to become a part of National Country Programme of the 2nd cycle of UNDP/UNIDO technical assistance with the objective to develop and implement an integrated computerized teleprocessing

oriented maintenance planning and management system. The project started in June 1979, with estimated and actual duration of 2.5 years, i.e. the project system development was completed in November 1981 with major follow-up implementation activities throughout 1982.

Czechoslovak Federal Ministry of Metallurgy and Heavy Engineering represented by INORGA Prague Research Institute for Industrial Management and Automation was appointed as a Government Cooperating Agency, providing the requisite framework, project management and counterpart organization in cooperation with VSŽ - East Slovakian Steelworks Košice, the latter providing direct counterpart platform for the proposed modern computerized maintenance management system development and implementation. The project costs were covered as follows :

The Government of ČSSR agreed to utilize for the project the existing computer facilities with the counterpart organizations to the value of US $ 2.5 million to cover for the project implementation requirements - these comprising inter alia the provision of salaries of counterpart personnel, building and both expendable and non-expendable equipment, computer time costs for programmes development, training costs, etc. These planned Government inputs were in the course of project implementation duly increased by 33.9% to the total of CS Crowns 22.9 million to cover the increased requirements of this large scale pilot project, in particular in the field of training, building habilitations, installations and non-expendable equipment.
UNDP/UNIDO originally agreed contribution to cover the project requirements in the field of training, consulting services and non-expendable and expendable equipment was US $ 0.912 million. These inputs were during the project implementation increased by 16.4%, the total actual contribution thus being US $ 1.062 million.

Apart from the project intangible benefits such as better information for decision making and easier and higher accurate control of maintenance work process, materials and spare parts supply as well as budgeting, smoother work load on a long term basis, standardization, etc., the annual concrete savings were achieved in the following areas :

	CS Crowns
- annual savings due to the lower inventory levels of spare parts	11.000,000
- annual savings due to the increased volume of assemblies and spare parts reconditioning	6.880,000
- annual savings due to the lower imports of spare parts	18.500,000
- annual savings due to the increased productivity of standardized assembly repairs (150 - 160 employees)	12.400,000
- annual savings due to the lower downtimes of key production facilities	9.239,000
- annual savings due to the increased facility loading in the spare parts manufacture areas	1.360,000
- annual savings due to the improved planning of repairs and manpower utilization (90 - 95 employees)	3.700,000
- annual savings due to the lower rescheduling of maintenance jobs and transportation times	240,000
Total annual savings CS Crowns	63.319,000

Considering the overall costs of CS Crowns 115.678 million for system development, routine operation and maintenance within the so called economic life of the system (i.e. period of 1979-89) and the corresponding total savings of CS Crowns 296.114 million stemming from the gradual system implementation during that period, the return ratio is approximately 3 years, i.e. the index of economic effectiveness per one CS Crown is 296.114/115.678 = 2.56 CS Crowns.

The information, views and conclusions presented in this paper are primarily based on the experience with the planning, management and implementation of this Czechoslovak UNDP/UNIDO project activities, i.e. major maintenance subsystems structuring and development, procurement and installation and operation of computer and communications hardware facilities, consultancy subcontracting and software packages development, extensive home and international training as well as the follow-up activities in the dissemination of know-how upon project completion. These experiences have been further complemented by the in sight gained during the studies of maintenance systems development in a number of developed and developing countries, including both United Nations and Government and/or Company sponsored projects.

2. Maintenance Function and Organization

2.1. Maintenance Functions and Activities

The primary function of a Maintenance Department is to maintain costly plant processing equipment and building facilities in an acceptable, operating and safe condition. The performance of this function requires technical expertise involving skilled craftsmen supported by maintenance shop equipment required in the repair of parts and/or their manufacture and efficient planning and management. The maintenance activities utilized to perform this function are therefore generally classified and referred to as maintenance shop services, maintenance field services and maintenance planning services.

a) Shop services are those associated with :
   - The repair and reconditioning of parts and assemblies involved in equipment breakdowns and maintenance.
   - The manufacture of new parts for replacement of spare parts inventories and/or on request.

b) Field services are those associated with :
   - The installation of equipments and parts.
   - The rehabilitation of building facilities.

- The replacement of worn or broken parts.
- The development and operation of preventive maintenance system including lubrication, inspection and testing.

c) Maintenance Planning Services are those associated with :

- The development and operation of a planning, processing and scheduling and monitoring systems for all orders prepared for maintenance shop and field activities.
- The development and operation of a spare parts and materials purchasing, stocking and inventory control system.
- The development and operation of costing system and budget for maintenance shop and field activities.

2.2. Maintenance Organizational Structure

In order to provide proper management of a Maintenance Department an organizational structure that sets forth clearly lines of authority and specifies accurately the inherent responsibilities of the management and planning positions involved is required.

The organizational structure will have a major effect on both plant availability and maintenance costs. In some plants, maintenance activities are decentralized, with specialists in the production departments. This self-sufficiency in maintenance can lead to overstaffing, and the increased specialization of craftsmen in many trades has caused many companies to create centrally organized maintenance functions, and to increase the automation of their workshops.

This centralization, however, brings about difficulties of its own. For onsite maintenance, it can be increasingly difficult to organize the maintenance work force in parallel with production. This often gives rise to unsatisfactory organizational structures, in which the technical responsibility that should be concentrated in one unit is spread over a number of organizational units.

When computer system is applied to maintenance planning and management, the advantages of decentralized plant maintenance can be combined with those of centralized maintenance. The more efficient use of manpower, the better distribution of the work load, and the possibilities of better long-term planning that centralization brings, can still be possible without physically removing the maintenance work force from the production areas they logically belong to. This solution of balanced mix of centralized and decentralized functions in the maintenance organization was applied in the case of Czechoslovak UNDP/UNIDO Project considering also other factors and/or conditions specific for the given works but general enough to be considered during any feasibility study on the maintenance organization structure.

These factors influencing maintenance organization are :

- Location. In some areas, external maintenance crews may be used during peak loads, or they may take over entire specialized maintenance tasks. Neighbouring plants also commonly loan spare parts to each other in an emergency.
- Technological standards. In some plants, advanced technology means that full-time maintenance specialists are required, making it possible to rely on outside help.
- Plant size. Small plants cannot fully employ the specialist they need. This leads them to build up large reserves, for example, of spare parts, and, in emergencies, to have to call in outside specialists under contract.
- Manpower. If work loads fluctuate, and if there are no stabilizing factors, external craftsmen can be called in during operating peaks. In this way, maintenance costs can be kept low during normal operating periods.
- Risks of breakdown. Equipment with a high risk of breakdown requires substantial backup services, in the form of standby facilities and a much larger maintenance work force.

2.3. General Functional Structure of Computerized Maintenance Management System (CMMS)

Based on the general maintenance functions as described above, the following functions and/or subsystems essentially create the general functional structure of a modern computer assisted maintenance system :

1) Maintenance Work Order Creation :
   - job requests
   - verification and work order generation
   - dispatching

2) Maintenance Planning :
   - plant catalog
   - preventive maintenance planning
   - repair planning
   - equipment lay-offs planning
   - material requirements planning
   - manpower requirements planning
   - maintenance cost planning

3) Inventory and Stores Management :
   - spare parts catalog
   - inventory recordkeeping
   - inventory control
   - parts and materials allocation
   - disbursement

4) Purchasing of Spares, Materials and Services :
   - purchase requisition
   - purchase order generation
   - vendor data update
   - followup

5) Spare Parts Manufacture and Reconditioning :
   - drawings
   - bills of material
   - routing operation
   - work stations
   - capacity planning and operation scheduling
   - shop floor monitoring and control

6) Maintenance Work Order Scheduling :
   - job selection
   - CPA method application
   - capacity planning and job scheduling
   - releasing maintenance jobs
   - dispatching
   - rescheduling

7) Maintenance Work Order Monitoring :
   - equipment lay-offs monitoring
   - maintenance orders monitoring
   - job status reporting
   - manpower loading and efficiency
   - maintenance cost monitoring

8) History and Analysis :
   - job completion reporting
   - maintenance cost analysis
   - equipment analysis
   - preventive maintenance and planned repair cycles and standards development

This general functional structure and additional necessary system hardware and software support activities have been embedded into the implementation of Czechoslovak UNDP/UNIDO Project through a comprehensive

set of the following interrelated Project activities :

A1 Project management and planning function
A2 Planning preventive maintenance and repairs
A3 Planning spare parts, semiproducts and materials
A4 Capacity planning and scheduling of maintenance work
A5 Inventory control and materials and spare parts purchasing
A6 Spare parts manufacture planning and control
A7 Maintenance monitoring
A8 Centralized data bank and coding systems
A9 Teleprocessing and application transactions support
A10 System hardware support
A11 Maintenance economics
A12 Experimental laboratory
A13 Microprocessor based diagnostics systems
A14 Computer aided parts programming
A15 Operational research modelling

Note : The reasons for the specification of and breakdowning the Project's work plan into these activities resulted from a detailed feasibility study and analysis.
These Project activities may be divided into five basic categories :

(1) Overall functions : A1, A11
(2) System development nucleus : A2, A3, A4, A5, A6
(3) System integration : A7, A8, A9
(4) Hardware support : A10, A12
(5) Specialized features : A13, A14, A15

From the above set of activities, A1 provides requisite framework for the overall Project - project planning, coordination and management, system documentation, training and transfer of know-how. The following five activities A2 - A6 represent the nucleus of the

maintenance system :

- Planning preventive maintenance and repairs
- Planning spare parts, semiproducts and materials
- Capacity planning and scheduling of maintenance work
- Inventory control and materials and spare parts purchasing
- Spare parts manufacture planning and control

They form,together with the following activity A7 (Maintenance Monitoring), the basic structure of the CMMS. For illustration of their global interrelationships and inputs/outputs, see Exhibit 3.

System integration and necessary links are provided by the next four activities A7 - A10, in particular the maintenance process monitoring in all these primary maintenance functions (A7), development of coding systems and data bank integration (A8), teleprocessing and transactions development (A9) and the hardware support, i.e. both central computer systems, communication network and terminal clusters (A10). The majority of these functions were developed for on-line system mode of operation which enables not only flexible operations management tool but also efficient combination of centralized and decentralized organization of maintenance.

Specialized modern features of the maintenance system are introduced through the implementation of activities A12 - A15. Activities A12 and A13 provide most up-to-date means of preventive maintenance - microprocessor based plant condition monitoring and diagnostics; A14 applies computer graphics to spare part programming and A15 is concerned with the application of Operational Research models in maintenance problems, in particular the Simulation and Network Analysis approach. The maintenance economics and cost/benefits analysis methodology are provided by A11.

2.4. Major Subsystems and Integrating Elements of CMMS

The five nucleus subsystems of CMMS are described bellow in terms of their development objectives and outputs, thus providing their overview description and structure.

1) Preventive Maintenance and Repairs Planning Subsystem

Development objectives :

Development and implementation of system modules for planning of inspections and preventive maintenance, repairs and overhauls and facility lay-offs with regard to maintenance ordering, inventories, spares manufacture, available manpower, maintenance costing and main production planning and/or scheduling.

Subsystem outputs :

For main production facilities, the subsystem, periodically or in requiry mode, provides for the following :

- long term plans of preventive maintenance and repairs (optional month, quarter, year or five-year horizon);
- long term gross requirements for spare parts/assemblies;
- gross plans of maintenance capacity requirements;
- maintenance costs planning.

In interactive mode and/or periodically in batch mode, the subsystem provides data entry, update and printouts for :

- maintained facilities catalog (covering production lines, machines, assemblies, parts);
- preventive maintenance/repairs cycles catalog;
- operations-and-standards-of-maintenance work catalog;
- maintenance work demands;
- maintenance work orders;
- job orders for maintenance work orders;

and also, enabled are enquiries in on-line and batch modes.

The flowchart of the subsystem depicting its modular structure, basic inputs/outputs and links with other maintenance subsystems is given in Exhibit 4.

2) Spare Parts, Semiproducts and Materials Requirements Planning Subsystem

Development objectives :

Development and implementation of system modules for assemblies, spares and materials requirements planning for both maintenance, reconditioning and/or manufacture purposes.

Subsystem outputs :

This subsystem, in interactive mode and/or periodically in batch mode, and in full variety of replacement parts and repaired/reconditioned/manufactured assemblies and materials needed, enables data entry and/or update for :

- variety of spare parts, assemblies, materials and semiproducts;
- requirements;
- requirements balancing;
- reservations to cover requirements;
- recommendations to purchase/manufacture/recondition.

Periodically, in enquiry mode and/or in on-line mode, this subsystem provides for the following management information :

- catalog of spare parts, assemblies, materials and semiproducts (with all relevant characteristics);
- requirements survey (including how-they-are-arranged-for-survey);
- reservations survey (with respect to stockpiles, purchase orders, and internal orders for manufacture, reconditioning and installation);
- net requirements balance;
- recommendation for purchase;

- recommendations for internal manufacture, reconditioning and installation.

The flowchart of the subsystem, depicting its modular structure, basic inputs/outputs and links with other CMMS subsystems, is given in Exhibit 5.

3) Capacity Planning and Scheduling of Maintenance Work Subsystem

Development objectives :

Maintenance manpower capacity planning and scheduling according to the maintenance and spare manufacture requirements and uniform manpower utilization objective, i.e. Preventive Maintenance and Repairs Planning Subsystem outputs scheduling. Actual usage monitoring and work effectiveness and productivity monitoring and evaluation can be, however, included within integrating functional modul - the global maintenance process monitoring.

Subsystem outputs :

For large scale repair operations, overhauls and revamps of production lines and machines, this subsystem periodically, in enquiry mode and/or in on-line mode, provides for the following :

- network catalog (network graphs);
- maintenance capacity resources catalog;
- network scheduling;
- resources balance for scheduled networks;
- job orders for releasing orders and jobs;
- preventive maintenance and repair orders schedules with start and completion terms, including job orders for maintenance work orders;
- survey of scheduled joint operations (on resources basis);
- resources catalog;

- survey of resources capacity loading;
- maintenance orders and job orders for release;
- work and accounting documents;
- survey of fulfillment of job orders for maintenance orders.

The flowchart of the subsystem is given in Exhibit 6.

4) Inventory Control and Materials and Spare Parts Purchasing Subsystem

Development objectives :

Development and implementation of a spare parts inventory control system, allocation and reservation of items for maintenance and manufacture orders, stockyard space utilization and the purchase control and vendor data update.

Subsystem outputs :

In interactive mode and/or periodically in batch mode, this subsystem enables data entry and/or update for :

- the variety of spare parts, assemblies, materials and semiproducts;
- the vendors;
- purchase orders and their items;
- internal orders for manufacture, reconditioning and installation and their items;
- reservations from stockpiles, from purchase orders and internal orders;
- inventory transactions and physical inventory takings;
- store locations.

This subsystem, periodically, in enquiry mode and/or in on-line mode, and in the full variety of replacement parts and repaired/reconditioned/manufactured assemblies and materials needed, provides for the following management information :

- catalog of spare parts, assemblies, materials and semiproducts (with all relevent characteristics);
- survey of the level and movements of inventories, including stockplace transactions (receipts, dispatches);
- reservations surveys (with respect to stockpiles, purchase orders, and internal orders);
- basic documents for physical inventory takings and physical inspections of the stockpiles (lubricants, protective varnish etc.);
- trends in requirements, purchase, manufacture, usage;
- catalog of storeplaces;
- survey of available and occupied storeplaces and movement frequency;
- vendors catalog;
- survey of purchase orders and their items;
- survey of internal orders for manufacture, reconditioning and installation;
- survey of deliveries completion.

The flowchart of the subsystem is given in Exhibit 7.

5) Spare Parts Manufacture Planning and Control Subsystem

Development objectives :

Development and implementation of a spare parts manufacturing and reconditioning planning and control subsystem, including drawings, bill of material processor, process routing, work centre capacity loading and scheduling, work in progresss monitoring.

Subsystem outputs :

For control of manufacture and reconditioning of spare parts, assemblies and semiproducts in central maintenance shopfloors, this subsystem, periodically in enquiry mode and/or in on-line

mode, provides for the following information :

- catalog of products and their components, including costing;
- drawing documentation catalog;
- catalog of manufacture, reconditioning and installation operations;
- catalog of individual machines and workplaces manufacture reconditioning and installation;
- rigs catalog;
- list of internal orders for manufacture, reconditioning and installation with order items included;
- schedule of internal orders and their items, including the start and completion terms for orders and products;
- survey of machines and workplaces capacity loading;
- short-term operations schedule for orders and machines;
- survey of to-be-released orders and operations;
- work, accounting and dispatching documents;
- survey of schedules fulfillment for orders, products and operations.

The flowchart of the subsystem is given in Exhibit 8.

The basic subsystems which form the CMMS nucleus are to be supported by the overall system functional modules, which can be either incorporated into individual subsystems (in case of stand alone, distributed implementation of individual CMMS subsystems) or create the overall system integration and thus contribute as the CMMS integrating elements. These overall system functions are primarily the Maintenance Monitoring Function and the System Software Support Functions - data bank and coding systems and teleprocessing and application transaction support.

1) CMMS Maintenance Monitoring Function

Development objectives :

Development of a general feedback system function - monitoring of results expected and/or planned through major functional subsystems, order handling, processing and coordinating. This subsystems function also includes monitoring analysis of statistical data and corresponding standards update.

Function outputs :

Implementation relates to the objective as given under the subsystems 1 - 5 while this function, in interactive mode and/or periodically in batch mode, provides data entry, update and printouts for :

- status and time utilization of Work's production facilities, and maintenance equipment and personnel;
- production facilities idle times and failures with evaluation included, based on time, type, cause, machine break down;
- progress of scheduled orders fulfillment.

In the area of historical files preparation and analysis of them, this function, periodically, in enquiry mode and/or in on-line mode, provides for the following management information :

- changes history for maintained facilities (production lines, machines, assemblies, parts);
- maintenance work history for production lines, machines, assemblies and parts;
- listings of jobs not completed;
- idle time and failure statistics;
- changes in cycle, operations schedules and standards for maintenance work;
- history of spare parts purchases, assemblies, materials and semiproducts;
- history of manufacture and reconditioning of spare parts,

assemblies, materials and semiproducts;
- consumption history for spare parts, assemblies, materials and semiproducts;
- changes in drawings, bills of material and manufacture/reconditioning operations.

The flowchart of the modules of this overall system function is given in Exhibit 9.
This function, like the following system software support function provides the integration of the modules and subsystems that are previously mentioned, specifically it provides the monitoring functions for all the nucleus CMMS subsystems.

2) CMMS Software Support Function

Development objective :
Development and implementation of an overall centralized Data Bank and coding systems servicing maintenance subsystems and/or activities as described above. Another important part is teleprocessing and application transactions support, i.e. a system for transactions processing for application needs of the maintenance subsystems and/or activities using a teleprocessing network and on-line man/machine enquiry concepts. Additional software programme support includes computer vendor supplied system software like IMS Operating System, Data Base Management System, application products, MRP, PMS, CAPOS, CLASS, etc.

Function outputs :
Software for initial loading and maintenance of :
- data catalog (including identifiers and codes);
- maintained facilities Data Bank;
- operations-and-standards-of-maintenance-work Data Bank;
- maintenance-work-orders Data Bank;
- Data Bank of spare parts, assemblies, materials and semiproducts;

- Data Bank of vendors for spare parts, assemblies, materials and semiproducts;
- Data Bank of manufacture and reconditioning of spare parts, assemblies and semiproducts;
- special tools and rigs Data Bank;
- replacement-assemblies-circulation Data Bank;
- remaining files;

of course with necessary checkup procedures/data protection included.

Software for teleprocessing :

- terminal network control independent of application programmes;
- transactions processing independent of the types of the terminals used;
- traffic control for input/output messages;
- dialogue (interactive) support for application programmes;
- dialogue monitor as a tool to increase programming productivity;
- specialized dialogue language enabling simple access to information in users Data Base.

3. Evaluation of the Multiple Aspects of CMMS Development and Implementation

3.1. System Development and Implementation

1) System modularity and integrity

The CMMS under development should be modular in both system functional structure design and computer programmes design and code. System modularity means that the overall system is broken down into subsystems, subsystems into modules, modules into functions, functions into functional tasks, etc. according to the problem logical structure. The higher systems components have one level, whilst the lower ones can have several levels. The functional

structure corresponds to the application areas and problem structure. The individual subsystems, moduls and lower components are to be directly operationally independant and/or with minor modifications only.
CMMS modularity enables stepwise system development and implementation and easier modification of various system modules and/or other components due to the changes as well as easier applicability to other conditions.

The CMMS should also provide through its common data bank organization, coding and identifier systems, system catalogue and standard transaction processing the system integrity which significantly contributes to the minimization of redundancy in both memory space and CPU processing and supports the comprehensive and general character of the system. Other features of the integrated CMMS include reliability, user friendliness (simplicity), maintainability, and effectivity.

2) Stepwise development and implementation

For CMMS successful development and implementation, the step-by-step development and implementation is essential, determining carefully the choice of priority subsystems and/or modules together with integrating activities during the feasibility study according to the available financial, hardware and human resources, maintenance organization, data collection and other factors. The system should be designed modular enough to render possible the gradual implementation.

Considerable attention must be paid to the selection of the pilot implementation area, according to the limitations of the equipment in the field, manpower and data collection possibilities, economic benefits and other specific criteria dependent on their weights and/or priorities which are able to achieve gradual

implementation using priority modules, reasonable balance between the overall implementation and pilot implementation should be made. The necessary condition is, however, that the system should be general enough to be implemented in all plant application areas.

3) Interactive System Design and Development

Modern system design and development approach based on both interactive, computer-based system and programmes development using different terminal clusters for the system design and documentation and programmes development and testing purposes proves to be highly efficient and essential to meet the prevailing tight schedules. The computer should be also used as project management tool for both network analysis, monitoring of costs, system catalogue, and computerized documentation.

3.2. Hardware and Software Support

The CMMS requirements for hardware and software support depend primarily upon the available financial and human resources, choice of centralized/integrated and/or distributed system design concept and other specific decision making aspects (e.g. licencing, leasing policies, engineering services etc.). However, based on the experience of the Czechoslovak UNDP/UNIDO project the following recommendations can be made.

1) Hardware support :

- a computer of 3 1/2 - 4 generation capable of teleprocessing mode of operation
- main memory with the range of 512 - 2048 Kbytes capacity
- random access disk memories with 500 - 800 Mbytes capacity (about 100 MB capacity per disk drive)

- sequential access magnetic tapes with 800/1600 b.p.i. density or higher (about 5 units)
- standard peripheral units including two line printers with min. speed 1400 lines per minute
- local terminal cluster for interactive system design and programming including about 5 displays and 3 hard copy printers (1920 characters per screen, 80 characters per sec. on printer)
- user terminal clusters for individual implementation areas with 2400 - 4800 bps half duplex teleprocessing lines and corresponding modems (the number of clusters according to the user/project requirements)
- standard data collection and data preparation equipment for data banks initial loading and large batch up-date (e.g. 8 - 12 key-to-disk systems).

The overall diagram of the system hardware configuration both at the computer centre and remote user areas of Eastslovakian Steelworks is given in Exhibit 10. The existing IBM 370/145 system with 1024 KB main memory was extended with CDC 512 Kbyte memory, five CDC 100 MByte disk storages, IBM magnetic tape units and IBM terminal equipment (display stations, printers, control units, modems, etc.). The limited number of terminals were results of the necessity to cope with the project financial budget ceilings.

Due to the large size of computer files and data bases and numerous plant areas, the usual CMMS applications have been based on mainframe computer concept. With the dynamic development of minicomputers this situation has, however, been recently changed, the distributed computers concept become feasible, sometimes also as a part of a company computer network. The distribution processing concept allows for a considerable degree of independency on the mainframe company computer but on the other hand, the CMMS functions are rather limited, usually confined to isolated applications.

2) Software Support

The software support for CMMS development and implementation can be divided into 4 categories :

a) Advanced computer operating system on OS level and compilers of higher languages (primarily Cobol and Fortran for majority of computers systems is preferable)

b) Data bank with data catalogue identification systems, data base generation, operation and maintenance protection

c) Teleprocessing support including facilities for the generation and operation of the teleprocessing nucleus, generation of the systems' transactions, programming of standard transactions, generation and operation of the enquiries system, etc.

d) Software programmes for interactive design, programming and editing and documentation.

All the above categories of the software can be provided by the computer vendor and/or software houses organizations; this particulary holds for (a) and (b) categories. This means that we have to rely on external vendors, upon licencing, leasing and other constraints, not to mention the financial ones. The alternative course of action is to design and develop own software, independently upon outside suppliers and fully matching our requirements; this of course, depends upon availability of highly skilled professional personnel as was the case with our project when software support for categories (c) and (d) was developed, in particular the STELA package for teleprocessing and APROS, SDT (System Design Technology) for system design and documentation and ASP cost monitoring package for project control.

STELA programme system was developed at VSŽ with the primary objective to extend the possibilities of the computer system users for the development of teleprocessing applications. The STELA programme system consists of 4 major parts :

- STELA/TC supports the application transactions from terminals independent formating of input/output messages using Cobol, Assembler and PL/1 languages
- STELA/DB creates interface between tne user and data access independently on various data organization and access methods and storage media
- STELA/QUELA provides a special inquiry language for selecting information from the user's data files
- STELA/CM as conversational monitor provides an efficient tool for increasing the programmers' productivity.

3.3. Human Resources

The broad scope of CMMS activities within limited span project duration and in many cases experimental, pilot character of the project requires considerable human resources for both system development and implementation. In fact, the effort of Project personnel represents the main key to the success of CMMS project. The following project personnel categories are to be planned :

- system analysts and designers
- application programmers
- system programmers
- users.

For the exact listed number of our project people, different project personnel categories and the scope of their involvement, see Table given below.

Table : Listed Number of Project Personnel

Project Personnel Category	Scope of Involvement	Listed Number
Project Management and managers from counterpart organizations	Both part time and full time	6
Project activity /subsystems/ team leaders	Primarily full time	15
System analysts and designers and application and system programmers who formed activity teams	Both part time and full time	46
System users participating in the system development and implementation work	All part time	16
Clerical and secretarial staff members who provided support for the above personnel	All part time	5

A prerequisite for efficient CMMS development and implementation is not only the number and qualifications of the project personnel but an effective organization and management of the project team. It is to be recommended to abolish "the classical" independent task group oriented approach and to incorporate the user implementation team into the system design team as well as using the programmers for the application programmes development in a pool form. For team organization concepts adopted in our CMMS project, see Exhibit 11.

Close co-operation of the project personnel is another important point. The co-operation between the system designers, analysts, programmers and users and the participation of the users on the system development, this is very important for the success of the project implementation.

The highly technical character of the CMMS project requires a systems approach not only in the area of computerized system development but also in the area of direct transfer of know-how.

During the preparatory stage and throughout the project implementation a comprehensive system of transfer of know-how was realized that included both acquirement of know-how and its dissemination and resulted in its ultimate effect in the preparatory process of establishment of a technical training and consultations centre for modern maintenance and production control systems in metallurgical and other basic industries.

The project direct acquirement of know-how consisted of an extensive programme of internal training (in ČSSR) and external training (study tour abroad) for various categories of EDP managers, system designers, programmers and users of both project and other organizations personnel in the form of training courses, seminars, workshops, study tours, fellowships, participation at conferences, exhibitions, etc.

1) Internal Training

Internal training courses were held throughout the project life span at both regular intervals and according to the requirements specified in project implementation plan and manpower education plans. These included courses and seminars of various technical categories (according to different project activities requirements) with duration from 1 to 10 days and the number of participants ranging from small groups of 5 to 10 to large groups of 40 - 50. The following number of total man-days were allocated to training in individual years of the project life span :

year 1 740 man-days,
year 2 880 man-days,
year 3 1,060 man-days.

The considerable build-up in the last year of the project represents primarily user training for the implementation purposes.

The training courses were provided by advanced academic institutions, vendors of the project hardware and software, activity and team leaders and participants of study tours abroad as well as project consultancy company personnel.

2) External Training

Under this heading are evaluated all other various training activities (fellowships, conferences, seminars, exhibitions, etc.) carried out abroad. The training programme abroad included about 19 main study tours that can be divided into the following three categories :

- advanced technical professional training (8 programmes),
- system design and management oriented training (6 programmes),
- user oriented training (5 programmes).

Participants were usually formed into small groups of 4 - 5 specialists.

The highly advanced professional training included participation at specialized courses organized by internationally renowned organizations in EDP field, namely INFOTECH London, Control Data Institute, NNCC Oslo, ISDOS and IFORS. For such participation considerable fees and registrations were charged.

User oriented study tours were oriented towards detailed on-spot study of implemented subsystems in multiple aspects of maintenance in specific metallurgical plants abroad. They were mainly organized jointly with the project consultancy company. For this type of study tour special training contracts were agreed to be covered by UNIDO subcontract.

The objectives of management and system design oriented study tours were to verify the principal system concepts, scope of implementation, system modularity and integration, hardware

and software support, manpower planning, transfer of know-how and managerial and educational aspects. Within these study tours the major steel corporations in Europe, Japan and the USA were visited and based on experience gained necessary conclusions for the project implementation were drawn. For these types of study tours no fees were paid, these being organized through bilateral agreements with Czechoslovak Iron and Steel Industry and their counterpart in respective countries.

Last but not least about 200 man-days of training of Czechoslovak technicians and programmers was carried out directly with the vendors of hardware equipment (IBM, CDC, Plessey).

Generally speaking, the requirements of know-how did not include these training events only - the whole process of system planning, design, programming, testing and implementation became a valuable learning process. A continuous process of acquirement of know-how for all categories of project staff is a logical prerequisite for successful system development and implementation.

3) Training of User Personnel

This is for CMMS implementation a most significant factor that cannot be overemphasized. Therefore, let us briefly summarize our approach and experience. The user training was carried out at 4 levels :

a) Training of maintenance top management with the objective to demonstrate the functions of the developed system according to various activities/subsystems, to clarify the basic principles and philosophy of the system and to describe the use of the system for top management information and decision making (minimum scope of this type of training is 2 days).

b) Training of maintenance line management with the objective

to make them aware of the overall system on general level, system philosophy and design approach on a detailed level, data stored in the system bank and individual databases, possibilities of information retrieval and transactions available at their specific field of management operations and responsibilities within system specific subsystem/activity and/or their combination (minimum scope of this type of training is 4 days).

c) Training of maintenance officers and planning to make them fully acquainted on a detailed level with the philosophy of their respective subsystem/activity area computerized operation, the use of system transactions and terminals in both on-line and batch mode of operation, data storage media, input/output formats, information retrieval for both their work and needs of the supervising management. This type of user personnel also participate at terminal operators' training(minimum scope of this type of training is 1 week).

d) Training of terminal operators and maintenance officers in the use and handling of system terminals (visual display units and hard copy printers) in their respective maintenance areas and the computer system facilities (minimum scope of instruction is 1/2 day, complemented by another 1/2 day of practical hands-on training).

The essential prerequisite for both successful user training and in particular, system implementation, is of course, availability of clear, concise and comprehensive user and operator documentation manual and the possibility of their easy and systematical up-date during further system improvements. Our experience has shown, too, that during the system introduction phase the trained user has to be supervised for at least two months of system operation commencement although this supervision need not to be full time activity.

3.4. Recommendations for CMMS Implementation

The previous parts 3.1. - 3.3. concerned with the CMMS development and implementation aspects including hardware and software support and organization and development of human resources through training implied a number of practical recommendations in these multiple aspects. As mentioned above, the CMMS development and implementation depends to a large extent upon the nature of the existing systems, both manual and computerized ones, the priorities of individual subsystems and/or modules decided by the management and during the design stage, available financial, hardware and human resources, maintenance organization, and many other factors. Nevertheless, the implementation sequence recommended below is of primary importance for modern CMMS implementation. It follows a clear and simple logical pattern; individual implementation steps, although many times overlapping and interacting, are recommended as follows :

Step 1

Stores inventory accounting and control is the recommended starting point for a CMMS application, and the parts usage history and inventory data acquired during this step will serve for the enquiry function of the spare parts and materials application, in the next step.

Step 2

When a work order creation system function is put into operation, the access to the stock number data base will allow work orders to be approved with full knowledge of the availability of parts. Dispatching of emergency work requests can be implemented at this time.

Job reporting can also be implemented since the data structure of this application is closely associated with the work order.

Step 3

From the data base built up from work order entry and job reporting, equipment and maintenance costs can start to be monitored and analysed. Obviously it is going to take a certain amount of time before there is sufficient data to be able to produce significant analysis.

Step 4

With access to the equipment history and spare parts data bases, the maintenance planner can start developing job plans and preventive maintenance schedules for the main production units.

As these plans are developed, they are stored in the data base and can be retrieved by equipment number, equipment class or condition, component, or action code for the type of report.

Step 5

The catalog of job plans can represent work standards, or the work standards can be extracted from the job plans. Once these standards are established, it is possible to compare the actual with the planned activity in order to report and analyze performance. This analysis can be according to the type of maintenance, plant area or craft.

Step 6

The next step might be to generate and update preventive maintenance schedule through analysis of the equipment history.

Step 7

In planning the job, an estimate is made of the manpower required. Once this is done, the jobs can be accumulated into job catalog,

arranged by priority, and scheduled according to available maintenance manpower. This is generally done periodicaly and allows for a great deal of interaction between maintenance and production management.

4. Dissemination of Know-how Activities

The dissemination of know-how upon CMMS project completion was effected inter alia through the following activities :

4.1. Direct and indirect transfer of know-how

1) Direct transfer of technology by trained INORGA and VSŽ personnel in the field of managed computerized maintenance systems to Czechoslovak Steel Industry.

2) Transfer of technology/expertise was further augmented through holding seminars/training courses/meetings at regular intervals as outlined in part 3.3. above.

3) Based on these Seminars/Training courses the specialized technology of CMMS was further transferred to ČSSR Industry and personnel through :

   a) effective use of existing computer equipment (on-line units, software and hardware) at the steel plants/industrial units and the optimum maintenance of the specialized computer equipment itself and their optimized operation.

   b) Interpretation of the computerized data/results and their application to industrial scale plant operations on a routine and periodic basic using various organizational bodies.

   c) Evaluation of the benefits achieved and transfer of technology and financial and technical gains acquired and their promotion towards industrial users.

4.2. Centralized Consultancy and Training Programme

Since the Czechoslovak as well as many developing countries' metallurgical, engineering and other basic industrial sectors' organizations can hardly cope with CMMS development problems individually, it appeared highly desirable to transfer the know-how from the pilot implementation of modern CMMS and the large scale UNDP/UNIDO project DP/CZE/77/005 "Application of Modern Maintenance System in Iron and Steel Industry" in particular, through a centralized Consultancy and Training Programme for maintenance managers, planners, engineers and computer specialists from both CSSR and interested developing countries, with the objective that such a centralized consultancy and training programme would allow for both broader dissemination of know-how and an important exchange of experience on the latest state-of-art, joint effective solutions of common problems and, which is even more important, provide an international cooperation and accumulation of training experience, teaching aids and facilities that were not available at that time. Through the Programme it was also envisaged to provide a platform for the future possible transfer of know-how in form of expertise. documentation, consultancy services, technical assistance and training to new users and specialists by long term modular training courses (with both more general and specialized topics), special on-site courses taylored to the special development needs through the establishment of a consultancy services and training centre on modern maintenance and production control system. As a result a follow-up project to DP/CZE/77/005 was prepared entitled "Preparatory Assistance in Establishing Consultancy and Training Centre on Modern Maintenance and Production Control Systems in Metallurgical Industries " (code number DP/CZE/80/001) with the primary objective to transfer the know-how from the above mentioned large scale project and thus to create a consultancy and training capacity which would, in turn,

serve as a background for establishment of a future formalized structure - a National Technical Consultancy and Training Centre. This project was fully implemented throughout 1981 - 1983.

4.3. National Technical Consultancy and Training Centre (NTCTC)

The basic objectives, concepts, organization and staffing requirements of the NTCTC were specified during the implementation of the "Preparatory Assistance" DP/CZE/80/001 project, including the drafting of the NTCTC project document and various necessary conditions for project document approval. Thus an institution building UNDP/UNIDO project "Establishment of a National Technical Consultancy and Training Centre" became operational, to be implemented during 1984 - 1986 by the integrated effort of four NTCTC partner organizations - INORGA Prague, VSŽ Košice, ŠKODA Plzeň and VUSTE Prague with the following immediate objectives :

1. To establish a National Technical Consultancy and Training Centre (NTCTC) for computer-based techniques in metallurgical, engineering and other basic industries.
2. To create within the Centre the following four functional capabilities :
   - Data bank capability
   - Capability to promote, sponsor and coordinate research and development
   - Consultancy services capability
   - Training services capability
3. To provide technical assistance and training in the field of computer applications for industry to developing countries at their request, possibly through and in collaboration with UNIDO.

This has provided the necessary grounds for the implementation of the efforts to increase the mutual technical cooperation among UNIDO member countries as stated during the UNIDO Third Consultation in Caracas, Venezuela in 1982 :

(a) It would be advisable to draw up, in each country, national training programmes offering advantages to on-site training and to arrange for inter-country exchanges of information with a view to identifying cooperation opportunities.

(b) Existing training centres in the developing countries should be opened to trainees from other countries; this has already been done in some cases, and such cooperation should be extended.

(c) Some relatively advanced developing countries could provide technical assistance in the field of design engineering, enterprise management, the training of trainers, and middle-level supervisory staff.

4.4. Approaches to International Cooperation

As mentioned earlier on, both Consultancy and Training capabilities can make a valuable contribution towards accelerating and strengthening the computerization and/or other industrial development of a country. The increasing number of Government requests of Technical Assistance to UNIDO in this field proves that the Governments are becoming more and more aware of the role of consultancy and training. Certainly the situation and needs in each country are different and consequently no standard approach or project can or should be considered. Furthermore, and in this particular field, traditional approaches of Technical Assistance, very often yield only average results.

It is to be underlined, that it is not only important here to consider what assistance is desirable, but also how such

assistance should be designed and how the programme is to be carried out. The mere sending of individual experts, even of terms, does not always allow for a sufficiently deep approach.

Although conditions may be different and so the inputs and objectives may differ, broadly speaking the following problem areas have frequently been identified :

a) Issues concerning establishment and operation of Consultancy and Training :

- Issues concerning the establishment, organization and development of a consultancy and training services.
- Questions concerning operational procedures, methodology and strategy of a consultancy and training services.
- Supplementing local skills through specialized consultants and trainers.
- Problems concerning international cooperation, joint ventures, exchange of experience, etc.

b) Issues within industry where Consultancy and Training can play a relevant role :

- Specific problems at the level of industry, such as production, maintenance management, finance, product development, engineering design, etc.
- Issues affecting organization, management, supervision and productivity of public sector enterprises and organizations.
- Development of skills and organizational concepts through operational activities and training.
- Specialized services in areas of government development policies, such as export orientation.

The above areas are mentioned in way of example. Problems (detected or undetected) exist in many other areas, but this presentation is limited to the most typical examples. However, it has to be mentioned, that in many cases the weakness or difficulties are not apparent, and so are only the results. Therefore in many

instancies a preliminary diagnostics which can take form of a preparatory assistance is advisable. Such assistance can, but not necessarily has to, lead to a large project. Many times the problems, once fully identified, can be solved through specialized, shortterm assistance, or even through adequatly oriented use of local resources.

Another fact which should be mentioned here is that particularly in this field approaches based on cooperation and exchange of experience between institutions, organizations, universities, etc. yield excellent results, either in the development of consultancy as a whole, or in any particular field, such as R and D. Such cooperation can be considered at national, but also at international level. Such schemes as TCDC offer an excellent platform for activities in this area. Valuable experience in development of consultancy and training exist in a number of developing countries, and a much wider use could be made of it with mutual advantages. In this place I would like to mention the preparation of our NTCTC twinning arrangements with the UNDP/UNIDO Regional Centre in ARE, based on similar computerized maintenance projects in Iron and Steel.

Preparatory Assistance/Diagnostics Missions

In this complex context of consultancy and expert services in developing countries any programme of Technical Assistance needs to be precisely defined from the outset. Such an assessment should not only define what objectives are desirable and possible, but also to define ways and means to achieve them. In such an assessment the following aspects are of particular importance :

(a) which assistance inputs can be effective;
(b) what can be achieved without any international inputs;
(c) how to combine international/national inputs.

In any case a diagnostic including recommendations for future is

advisable. Should from the outset be assumed that international inputs are necessary, the initial action would take the form of a preparatory assistance; should the contrary be the case, the activities will take the form of diagnostic mission, which would define future local policies, actions, programmes necessary to be carried out with local resources. Operationally both types of activity at this stage are similar, and would require a number of experts integrated into a team. A typical team would consist of :

a) Expert in organization of consultancy, for the overall assessment of present situation and possibilities of development (it is to be noted that such an assessment also requires an analysis of existing and potential demand).

b) Expert in training and development of staff.

c) Specialized experts as required in individual disciplines or subjects such as management, organization of production, quality product, and product development, etc.

During such phase full possibilities of improving the situation through mobilization of local resources should be determined. Here references could be made to the cooperation of universities, full use by consultancy of R and D local facilities, etc. In this connection I would like to mention our fact finding missions to Algeria resulting in the assignment of Czechoslovak experts to Annaba El Hadjar Steel complex and the preparatory work for a joint maintenance project.

Expert and Consultancy Services Project

Projects in the field of consultancy development, deal usually with a variety of problems some of them external to consultancy itself, but of importance for the future of such services. In a way of example such areas as adaptation of technology, export development, better use of natural resources, can be mentioned. The duration and nature of a project depends very much on the present and potential situation

of a country, the concept of consultancy to be developed, and the objectives of the Government. The project, and consequently the inputs, are to be designed accordingly. Once again, the importance of producing an adequate "mix" of inputs, such as expert services, training, cooperation with other consultancy services is to be stressed.

The expert services are in some instances only of limited effectiveness. Another type of inputs, particularly in case of already fully operating consultancy services would be provision of services of fully experienced and qualified consultancy firm, to strengthen during a period of time the services of a consultancy firm in developing countries, and also to provide an intensive operational training programme. It is to be observed that such a programme could be considered as a priority TCDC operation, i.e. sharing the results and experiencies from previous UN projects.

Provision of a consultancy contract over a period of e.g. six months providing assistance in operational strengthening and training of consultancy (approx. 18 m/m of consultants in field and 4 m/m HQ - consultancy - support, including documentation, elaboration of programme, etc.) could be another example of the transfer of know-how process. The length and number of consultants differs, of-course, for different specific situations, in case of CMMS the most convenient solution extends over the whole life span of the project.

One of the issues of the development of consultancy is the lack of international experience, and also a lack of access to solution or approaches, developed in other countries, with similar background. A cooperation in such respect can produce excellent results. As an example of the possibility of such a cooperation I would like to mention the UNDP/UNIDO pipeline project for integrated computerized maintenance system for ROURKELA/BOKARO steel plants of SAIL in India where the concepts involved started during a Group Training Programme in this field in this country two years ago.